Vysokorýchlostné siete LAN

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Last Update: 30 Nov 2004

LAN siete o rýchlostiach 100 Mbps

Najrozšírenejšie vysokorýchlostné LAN siete sú založené na technológiách 10Mbps Ethernet, resp. IEEE 802.3, pričom sú rozšírené siete o rýchlostiach 100Mbps a 1Gbps. Prvým zvýšení rýchlosti z 10Mbps bol upgrade na 100Mbps, tzv. **Fast Ethernet**.

IEEE pracovalo na špecifikáciách vysokorýchlostného 100Mbps Ethernetu. Nedohodli sa však úplne na tom, či zachovajú pôvodnú MAC metódu (CSMA/CD) alebo zadefinujú novú. Tak vznikli dve grupy a následne aj dve špecifikácie – 100BaseT a 100VG-AnyLAN.

100VG-AnyLAN (802.12)

- špecifikácia pre 100Mbps Ethernet a Token Ring na štvorpárovom UTP
- MAC nie je kompatibilná s 802.3
- bola vyvinutá v HP pre nové, time-sensitive aplikácie ako upgrade z Ethernetu a TokenRingu
- podporuje rôzne druhy médií (4páry UTP cat3, 2 páry UTP cat4 alebo cat5, STP, Fiber optic)
- 100VG-AnyLAN HUBy sú v hierarchickej štruktúre
- používa demand-priority access method – eliminuje kolízie, môže byť viac zaťažený ako 100BaseT
- Demand Priority works like this: The hub directs all transmissions, acknowledging higher-priority packet requests before normal-priority requests. This effectively guarantees bandwidth to time-sensitive applications like voice, video, and multimedia applications.

Štandardy 802.3

V IEEE sú pod 802.3 zriadené task forces 802.3**xy**, každá sa venuje špecifickej oblasti.

Štandard 802.3 bol naposledy prevydaný v roku 2002 ako:
IEEE Std 802.3™-2002 (Revision of IEEE Std 802.3, 2000 Edition).
Delí sa na tri sekcie, ktoré obsahujú špecifikáciu 10, 100 a 1000 Mbps CSMA/CD sietí. Odvtedy pribudlo niekoľko dodatkov. Štandard a jeho dodatky je možné downloadovať z www.ieee.org (15MB, 1500strán).

Supplement	Year	Description
802.3a	1985	10Base-2 (thin Ethernet)
802.3c	1986	10 Mb/s repeater specifications (clause 9)
802.3d	1987	FOIRL (fiber optic inter repeater link)
802.3i	1990	10Base-T (twisted pair)
802.3j	1993	10Base-F (fiber optics)
802.3u	1995	100Base-T (Fast Ethernet and autonegotiation)
802.3x	1997	Full duplex
802.3z	1998	1000Base-X (Gigabit Ethernet)
802.3ab	1999	1000Base-T (Gigabit Ethernet over twisted pair)
802.3ac	1998	VLAN tag (frame size extension to 1522 bytes)
802.3ad	2000	Parallel links (link aggregation)
IEEE Std 802.3™-2002	2002	prevydanie, zahŕňa všetky dodatky dovtedy (1538 strán:)
802.3ae	2002	Amendment: 10-Gigabit Ethernet
802.3af	2003	Amendment: Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)
802.3aj	2003	Amendment: Maintenance 7
802.3ah	2004	Amendment: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks
802.3ak	2004	Amendment: Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4

100BaseT

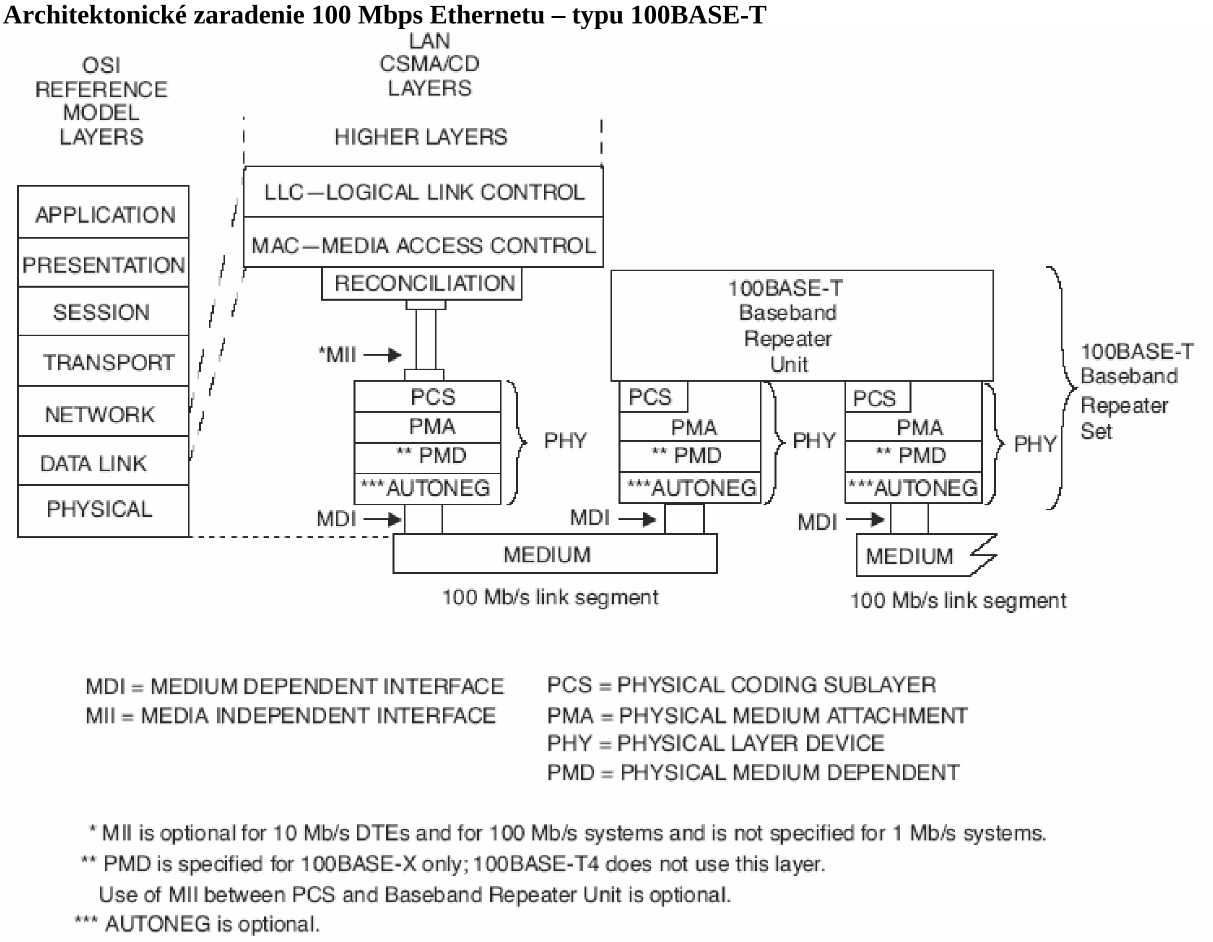
pôvodne špecifikovaný ako **802.3u**, teraz sekcia II v EEE Std 802.3™-2002.

100BASE-T spája IEEE 802.3 CSMA/CD MAC podvrstvu s rodinou nových 100 Mbps Physical Layers.

100BASE-T využíva existujúci IEEE 802.3 MAC layer interface prepojený cez Media-Independent Interface layer na príslušnú Physical Layer entity (PHY) podvrtvu (napr. 100BASE-T4, 100BASE-TX, or 100BASE-FX).

100BASE-T extends the IEEE 802.3 MAC to 100 Mb/s. The bit rate is faster, bit times are shorter, packet transmission times are reduced, and cable delay budgets are smaller—all in proportion to the change in bandwidth. This means that the ratio of packet duration to network propagation delay for 100BASE-T is the same as for 10BASE-T.

Architektonické zaradenie 100 Mbps Ethernetu – typu 100BASE-T



This MII is capable of supporting both 10 Mb/s and 100 Mb/s data rates through four bit wide (nibble wide) transmit and receive paths. The **Reconciliation sublayer** provides a mapping between the signals provided at the MII and the MAC/PLS service definition.

The following portion of this standard specifies a family of Physical Layer implementations.
100BASE-T4 (Clause 23) uses four pairs of ISO/IEC 11801 Category 3, 4, or 5 balanced cabling.
100BASE-TX (Clauses24 and 25) uses two pairs of Category 5 balanced cabling or 150 Ω shielded balanced cabling as defined by ISO/IEC 11801.
100BASE-FX (Clauses 24 and 26) uses two multi-mode fibers.
FDDI (ISO/IEC 9314 and ANSI X3T12) Physical Layers are used to provide 100BASE-TX and 100BASE-FX physical signaling channels, which are defined under 100BASE-X (Clause 24).
100BASE-T2 (Clause 32) uses two pairs of ISO/IEC 11801 Category 3, 4, or 5 balanced cabling.

100BaseT

Špecifikuje 100Mbps Ethernet na UTP a STP kabeláži štandardizované ako **802.3u**. MAC podvrstva zachováva kompatibilnú s MAC podvrstvou špecifikácie 802.3. Okrem MAC metódy zachováva aj formát a veľkosť rámca, error-detection mechanizmus. Podporuje dual speed, t.j. 10 a 100 Mbps použitím 100BaseT fast link pulses (FLPs). Convergence podvrstva kóduje dáta do 4-bitov pre MII a do MAC podvrstvy prepája carrier sense a colision detection signal generované z PMD podvrstvy. Podporuje dva typy signalizácie - 100BaseX a 4T+.

Signalizácia 100BaseX používa kódovanie 4B5B (výsledná baudová rýchlosť 125MBd), pre prácu jej postačujú dva páry vodičov ako pri 10Mbps. Toto kódovanie navyše umožuje využiť zvyšné kódové slová na link control funkcie ($2^4 = 16$, $2^5 = 32$ => mám ešte 16 slov navyše). Je použitá pri **100BaseTX** a **100BaseFX** typoch médií.

Signalizácia 4T+ používa 1 pár vodičov na detekciu kolízie a ďalšie 3 na prenos údajov. Používa kódovanie 8B6T, teda osmicu bitov do šestíc ternárnych (trojúrovňových) symbolov. Baudová rýchlosť je potom 33MBd a umožňuje 100Mbps prenos na kabeláži UTP category 3. Pretože kódujeme osmice do šestíc ide o kódovanie 8B6T kde máme $2^8 = 256$ vstupných slov a $3^6 = 729$ možných kódových slov. Táto redundancia sa využíva na synchronizáciu a elimináciu jednosmernej zložky (DC-free). Je použitá pri **100BaseT4** type média, podporuje **iba poloduplex**.

Ešte existuje špecifikácia **100BaseT2**, ktorá umožňuje 100Mbps prenos na kabeláži UTP category 3 po dvoch pároch, pričom využíva kódovanie PAM5x5 (výsledná baudová rýchlosť 25MBd).

Hlavný rozdiel technológie 100BaseT oproti 10BaseT je okrem rýchlosti diameter siete. Jeho veľkosť je 205 metrov z čoho vyplýva maximálna vzdialenosť medzi HUBom a DTE cca 100 metrov. To je asi 10x menej ako pri 10Mbps. Táto redukcia je kvôli tomu, že stanica aj pri prenose najmenšieho rámca (64B) musí vedieť detekovať kolíziu. Pretože rýchlosť šírenia signálu je rovnaká, ale prenosová rýchlosť sa zvýšila 10x, tak bolo potrebné zmenšiť maximálnu vzdialenosť 10x.

Prostredníctvom tzv. **Fast link pulses** táto technológia kontroluje integritu linky medzi HUBom a 100BaseT zariadením a podporuje tzv. 100BaseT Autonegotiation Option, pomocou ktorej umožňuje zariadeniu a HUBu vymieňať informácie o ich možnostiach, dohodnúť si prenosovú rýchlosť (10 alebo 100Mbps), prenosový mód (full-duplex alebo polo-duplex) a typ použitej signalizácie (pri staniciach 100BaseT4 a 100BaseTX).
FPLs sú spätne kompatibilné s 10BaseT normal-link pulses (NLPs) používanými na kontrolu integrity linky, obsahujú však viac info ako NLP, ktoré sú používané pri opísanom autonegociačnom procese medzi HUBom a zariadením na sieti.

Fast Ethernet devices that support auto-negotiation send fast link pulses (FLP) to the adjacent link station to negotiate the SPEED and MODE of the link. The FLP signals carry information necessary to negotiate the highest level of service available for the link. The priority for services includes 100BaseTX full-duplex as the highest priority, then 100BaseT4, 100BaseTX, 10BaseT Full-Duplex, and finally 10BaseT (which has the lowest priority).

Charakteristiky troch druhov 100BaseT sietí:

<table>
<tr><td colspan="3">vyššie vrstvy</td></tr>
<tr><td colspan="3">LLC podvrstva</td></tr>
<tr><td colspan="3">802.3 MAC podvrstva</td></tr>
<tr><td>100BaseTX
UTP cat.5, STP Type1,2
2 páry
segment ≤ 100m
network diameter ≤ 200m</td><td>100BaseFX
62,5/125μm multimód
1 pár optických vlákien
segment ≤ 400m
network diameter ≤ 400m</td><td>100BaseT4
UTP cat.3, 4, 5
4 páry
segment ≤ 100m
network diameter ≤ 200m</td></tr>
</table>

Figure 7-10 The 100BaseTX is limited to a link distance of 100 meters.

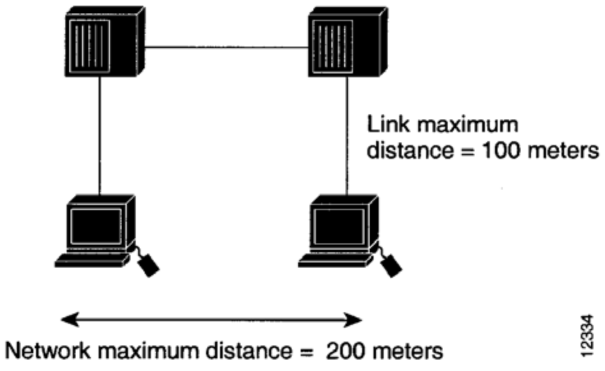
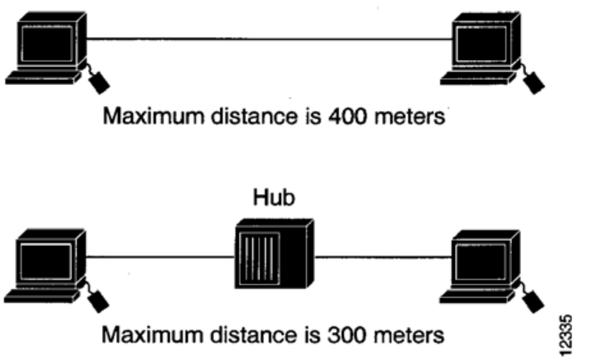


Figure 7-11 The 100BaseFX DTE-to-DTE limit is 400 meters.



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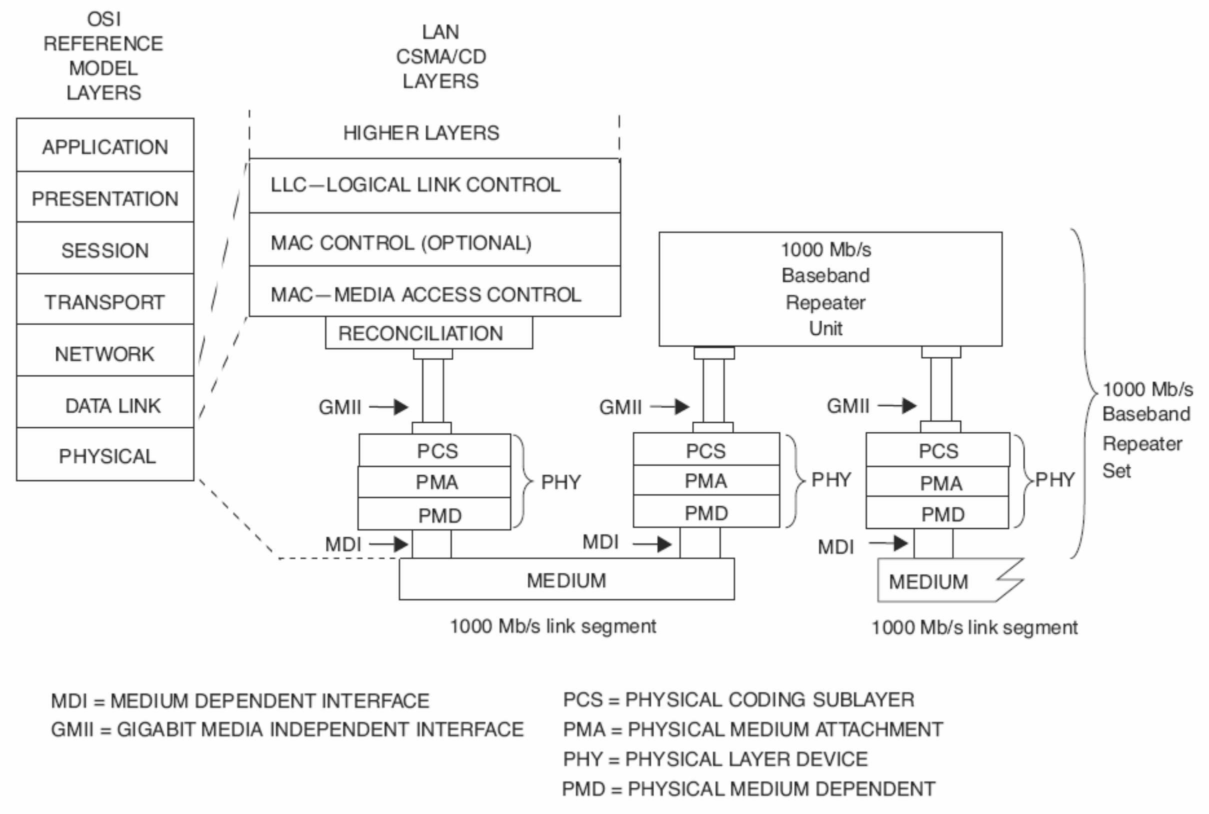
Gigabitový Ethernet

Gigabit Ethernet uses the extended ISO/IEC 8802-3 MAC layer interface, connected through a Gigabit Media Independent Interface layer to Physical Layer entities (PHY sublayers) such as 1000BASE-LX, 1000BASE-SX, and 1000BASE-CX, and 1000BASE-T.

Gigabit Ethernet extends the ISO/IEC 8802-3 MAC beyond 100 Mb/s to 1000 Mb/s. The bit rate is faster, and the bit times are shorter—both in proportion to the change in bandwidth. In full duplex mode, the minimum packet transmission time has been reduced by a factor of ten. **Achievable topologies** for 1000 Mb/s full duplex operation **are comparable to** those found in **100BASE-T** full duplex mode. In half duplex mode, the minimum packet transmission time has been reduced, but not by a factor of ten. Cable delay budgets are similar to those in 100BASE-T. The resulting achievable topologies for the half duplex 1000 Mb/s CSMA/CD MAC are similar to those found in half duplex 100BASE-T.

Architektonické zaradenie Gigabitového Ethernetu



The Gigabit Media Independent Interface (Clause 35) provides an interconnection between the Media Access Control (MAC) sublayer and Physical Layer entities (PHY) and between PHY Layer and Station Management (STA) entities. This GMII supports 1000 Mb/s operation through its eight bit wide (octet wide) transmit and receive paths. The Reconciliation sublayer provides a mapping between the signals provided at the GMII and the MAC/PLS service definition.

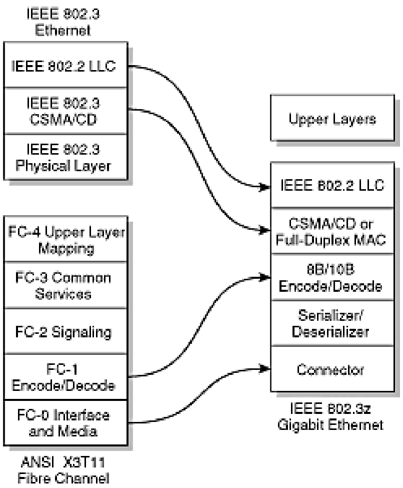
The term **1000BASE-X** refers to a specific family of physical layer implementations specified in Clauses 36–39. The 1000BASE-X family of physical layer standards has been adapted from the ANSI X3.230-1994 [B20] (Fibre Channel) FC-0 and FC-1 physical layer specifications and the associated 8B/10B data coding method. The 1000BASE-X family of physical layer implementations is composed of **1000BASE-SX**, **1000BASE-LX**, and **1000BASE-CX**. All 1000BASE-X PHY devices share the use of common PCS, PMA, and Auto-Negotiation specifications.

The **1000BASE-T PHY** (Clause 40) uses four pairs of Category 5 balanced copper cabling. Clause 40 defines its own PCS, which does not use 8B/10B coding.

Gigabit Ethernet - rozšírenie štandardu IEEE 802.3 na rýchlosť 1Gbps. Štandard IEEE 802.3z Gigabit Ethernet definuje Gigabitový Ethernet na optických médiách a na koaxiálnom kábli. Štandard 802.3ab definuje 1Gb Ethernet na kabeláži UTP. Podobne ako pri 100BaseT aj 1000Base-LX (SX, CX, T) umožňujú autonegociačnú option, a umožňujú dohodnúť full-duplex prenos na rýchlosti 1000 Mbps.

- zlúčením štandardov IEEE 802.3/Ethernet (LLC, prístupová metóda a frame format) a ANSI X3T11 Fibre Channel (médium, interface, encoding) vznikol štandard IEEE 802.3z Gigabit Ethernet.
- bolo potrebných niekoľko zmien na fyzickom interface
- od data-link vrstvy je identický s Ethernetom

Leveraging these two technologies means that the standard can take advantage of the existing high-speed physical interface technology of FibreChannel while maintaining the IEEE 802.3 Ethernet frame format, backward compatibility for installed media, and use of full- or half-duplex carrier sense multiple access collision detect (CSMA/CD).



Samotná MAC podvrstva je podobná ako pri Ethernete a Fast Ethernete (formát rámcov, prístupová metóda, network diameter).

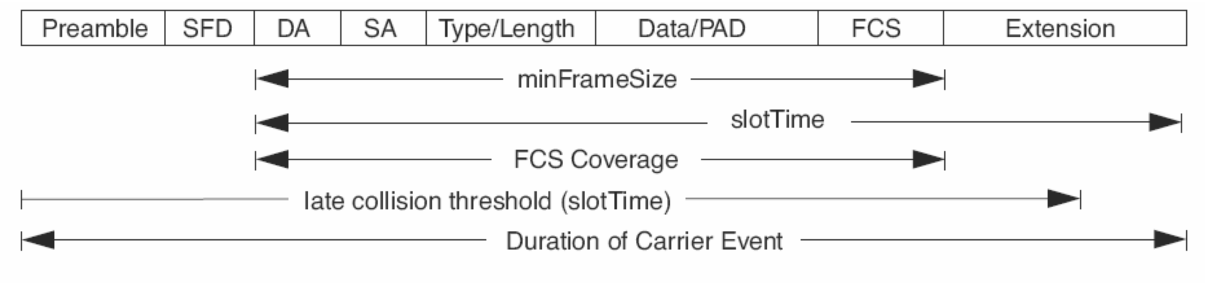
Používaný je hlavne **full-duplex** mód, určený pre point-to-point linky, typicky medzi dvomi switchmi, servermi a pod. Agregovaná kapacita dosahuje 2Gbps, pri použití zväzkov až 8Gbps. Full duplex prenos môže byť zriadený iba na point-to-point linkách, flow control metóda je definovaná štandardom 802.3x (tento štandard nie je použitý pri 100Mbps full-duplexe).

Umožňuje **half-duplex** prenos, kedy je použitá rovnaká CSMA/CD. Kvôli možnosti detekcie najkratšieho rámca (tzv. Slot time) sa musia pridať bity za rámec (carrier extention) s cieľom dodržať minimálnu dĺžku 520B pre 1000BaseT a 416B pre 1000Base-X. Navyše ako optional feature umožňuje frame bursting (stanica môže naraz vyslať celý burst rámcov). V každom prípade je half-duplex mód z hľadiska využitia kapacity veľmi neefektívny a preto **sa prakticky ani nepoužíva**.

The following table identifies the parameter values that shall be used in the 10, 100 and 1000 Mb/s implementation of a CSMA/CD MAC procedure:

Parameters	10 Mbps	100 Mbps	1000 Mbps
slotTime	512 bit times	512 bit times	4096 bit times
interFrameGap	9.6 µs	0.96µs	0.096µs
attemptLimit	16	16	16
backoffLimit	10	10	10
jamSize	32 bits	32 bits	32 bits
maxUntaggedFrameSize	1518 octets	1518 octets	1518 octets
minFrameSize	512 bits (64 octets)	512 bits (64 octets)	512 bits (64 octets)
burstLimit	not applicable	not applicable	65 536 bits

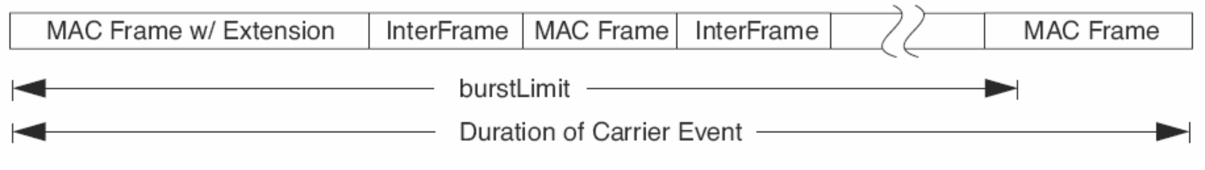
MAC Frame with Gigabit Carrier Extension
(Half-Duplex mode only)
At operating speeds above 100 Mb/s, the slotTime employed at slower speeds is inadequate to accommodate network topologies of the desired physical extent. Carrier Extension provides a means by which the slotTime can be increased to a sufficient value for the desired topologies, without increasing the minFrameSizeparameter, as this would have deleterious effects. **Nondata bits**, referred to as **extension bits**, are appended toframes that are less than slotTime bits in length so that the resulting transmission is at least one slotTime induration. Carrier Extension can be performed only if the underlying physical layer is capable of sending and receiving symbols that are readily distinguished from data symbols, as is the case in most physical layers that use a block encoding/decoding scheme. The maximum length of the extension is equal to the quantity (slotTime – minFrameSize). Followind figure depicts a frame with carrier extension.



The **extension field is automatically removed** during frame reception.
Duration of Carrier Event – 416Bytes for 1000BASE-X, 520Bytes for 1000BASE-T

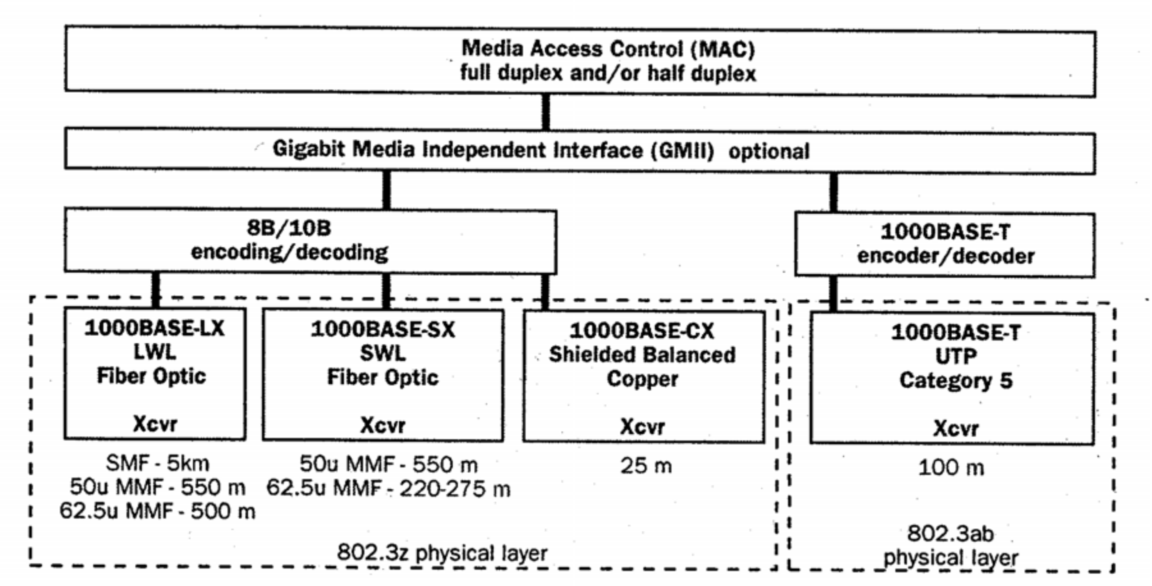
A Gigabit Frame-Bursting
(Half-Duplex mode only)

- Another change to the Ethernet CSMA/CD transmit specification was the addition of frame bursting for gigabit operation. Burst mode is a feature that allows a MAC to send a short sequence (a burst) of frames equal to approximately 5.4 maximum-length frames without having to relinquish control of the medium. The transmitting MAC fills each interframe interval with extension bits, as shown in Figure 7-8, so that other stations on the network will see that the network is busy and will not attempt transmission until after the burst is complete. iba pri Half-duplexe, pri rýchlostiach nad 100Mbps
- je to optional, tzv. burst mód
- umožňuje vyslať viacero rámcov bezprostredne za sebou bez uvoľnenia spoločného média
- The transmitting station fills the interframe spacing interval with extension bits, which are readily distinguished from data bits at the receiving stations, and which maintain the detection of carrier in the receiving stations. The transmitting station is allowed to initiate frame transmission until a specified limit, referred to as burstLimit (65 536bits, or 8192 Bytes), is reached.
- If the length of the first frame is less than the minimum frame length, an extension field is added to extend the frame length. Subsequent frames in a frame-burst sequence do not need extension fields, and a frame burst may continue as long as the burst limit has not been reached. If the burst limit is reached after a frame transmission has begun, transmission is allowed to continue until that entire frame has been sent.



Jumbo Frames
V roku 1998 Alteon Networks, Inc. iniciovalo aktivitu na zväčšenie veľkosti MAC Data poľna, z 1500B na 9000B, kvôli vyššej efektivite prenosu. Nebolo to akceptované a zahrnuté do štandardu 802.3, ale viacerí výrobcovia toto podporujú ako option pri full-duplex prenose.

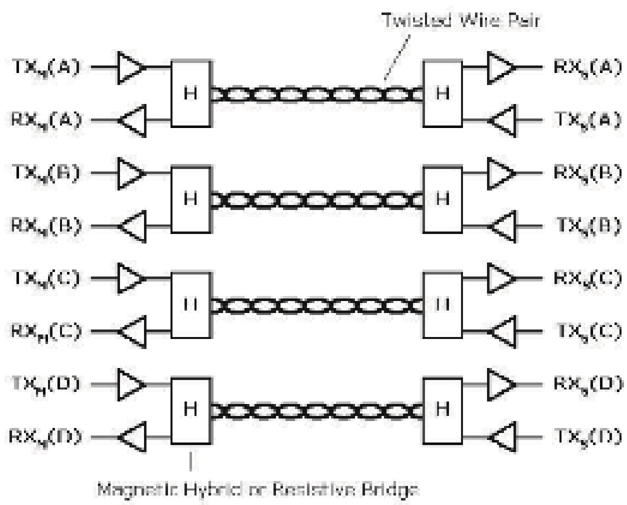
Jednotlivé vrstvy pri štandardoch Gigabitového Ethernetu vyzerajú nasledovne:



1000BASE-SX Short Wave Length Optical	Duplex multimode fibers
1000BASE-LX Long Wave Length Optical	Duplex single-mode fibers or Duplex multimode fibers
1000BASE-CX Shielded Jumper Cable	Two pairs of specialized balanced cabling
1000BASE-T Category 5 UTP	Advanced multilevel signaling over four pairs of Category 5 balanced copper cabling

- 802.3ab definuje 1Gb Ethernet na UTP

In order to obtain the 1000Mbps data bit rate across the UTP cable without breaking the FCC rules for emission, all 4 pairs of the cable are used. Hybrid circuits at each end of each pair are used to allow simultaneous transmission and reception of data (full-duplex) by separating the transmission signal from the receiving signal. Because some transmission signal still manages to couple itself to the receiving side there is an additional echo canceller built in, this is called a NEXT canceller. This system minimises the symbol rate.

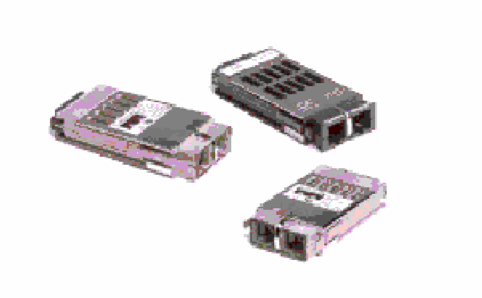


Gigabit Ethernet Interface Carrier (GBIC)
Pretože existuje relatívne veľa špecifikácií fyzických prenosových médií pre Gigabitový Ethernet, bolo by nepraktické konštruovať zariadenia s interfejsami napevno zabudovanými. Preto bol definovaný tzv. *GBIC interface*, ktorý umožňuje použiť zásuvné moduly do zariadení (napr. Switch-ov).

A **GBIC** is a transceiver for gigabit ethernet. The name is an acronym for "gigabit interface converter". A GBIC measures 8.5 mm x 13.4 mm on its exposed edge and fits into a slot about 50 mm deep. By offering a standard, hot swappable electrical interface, one gigabit ethernet port can support the full range of physical media, from copper to 100 km single-mode fiber.

Dimensions (H x W x D): 8.5 mm x 13.4 mm x 56.5 mm

Cisco Gigabit Interface Converters]



3.1 Cisco 1000BASE-T GBIC

The Cisco 1000BASE-T GBIC (product number WS-G5483) connects a GBIC port to Category 5 wiring via a standard RJ-45 interface. The maximum Category 5 wiring distance is 328 feet (100 meters). For details, see the *Cisco 1000BASE-T Gigabit Interface Converter Data Sheet*.

3.2 Cisco 1000BASE-SX GBIC

The Cisco 1000BASE-SX GBIC (WS-G5484) operates on ordinary multimode fiber (MMF) optic link spans up to 1815 feet (550 m) long.

3.3 Cisco 1000BASE-LX/LH GBIC

The Cisco 1000BASE-LX/LH GBIC (WS-G5486) fully complies with the IEEE 802.3z 1000BASE-LX standard. However, its higher optical quality allows it to reach 6.2 miles (10 kilometers) over single-mode fiber (SMF), compared with the 3.1 miles (5 km) specified in the standard.

3.4 Cisco 1000BASE-ZX GBIC

The Cisco 1000BASE-ZX GBIC (WS-G5487) operates on ordinary single-mode fiber optic link spans up to 43.4 miles (70 km) long. Link spans of up to 62 miles (100 km) are possible using premium single-mode fiber or dispersion shifted single-mode fiber. The GBIC provides an optical link budget of 23 dB—the precise link span length will depend on multiple factors such as fiber quality, number of splices, and connectors.

When shorter distances of single-mode fiber are used, it might be necessary to insert an in-line optical attenuator in the link to avoid overloading the receiver:

- A 5-dB or 10-dB inline optical attenuator should be inserted between the fiber-optic cable plant and the receiving port on the Cisco 1000BASE-ZX GBIC at each end of the link whenever the fiber-optic cable span is less than 15.5 miles (25 km).

Mini GBIC SFP

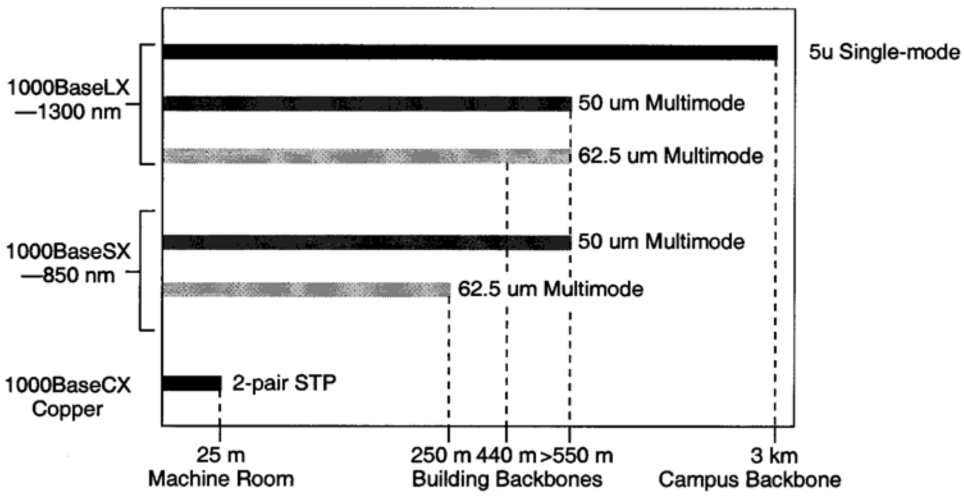
Gigabit Ethernet Mini GBIC SFP Transceivers. All GoCables Transceivers are **S**mall **F**orm Factor **P**luggable Multi-Source Agreement (SFP MSA)
Dimensions (WxDxH) 0.6 in x 2.8 in x 0.6 in

Gigabit Ethernet prenosové médiá

optické mediá, koaxiál
- Physical media attachment (PMA) sublayer je zhodná s PMA pre Fiber Channel, iba rýchlosť signalizácie bola zvýšená z 1,062 gigabaud na 1,25 Gbaud
- 8B/10 encoding

twisted pair
- 1000Base-T – UTP
- kódovanie 5 level PAM – naraz kódujem 2 bity, 1 úroveň mám na FEC, pri 125Mbaud

Figure 7-18 The Gigabit Ethernet draft specifies these distance specifications for Gigabit Ethernet.



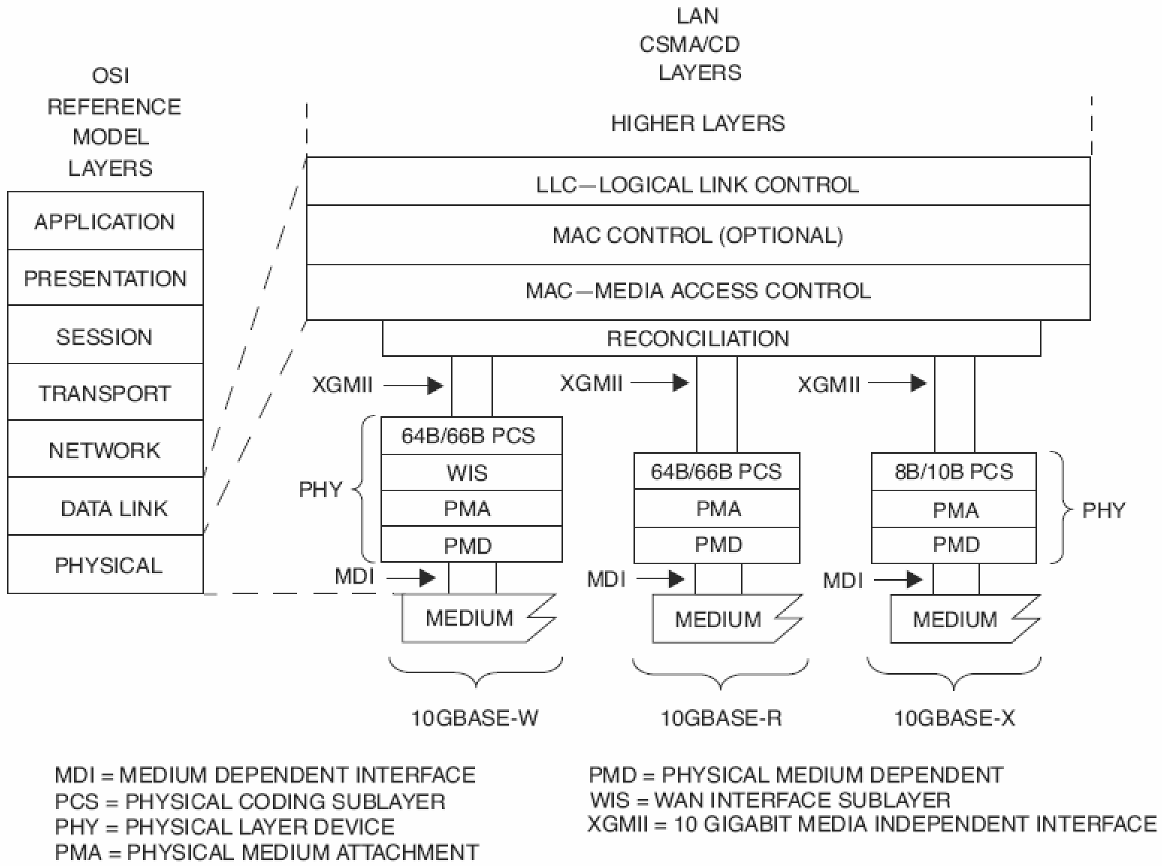
Automatic MDI/MDI--XX
- the main role of the Automatic MDI/MDI-X is to eliminate the need for using crossover cables between similar devices
- implementation of an automatic MDI/MDI-X configuration is optional for 1000BASE-T
- able to randomly switch between MDI and MDI-X configuration after listening for Fast Link Pulses (FLPs) for a specified amount of time (62 ±2 ms)

Although the automatic MDI/MDI-X configuration is not required for successful operation of 1000BASE-T, it is a functional requirement that a crossover function be implemented in every link segment to support the operation of Auto-Negotiation. The crossover function connects the transmitters of one PHY to the receivers of the PHY at the other end of the link segment.

10 Gigabit Ethernet

10-gigabit Ethernet (XGbE or 10GbE) is the most recent (as of 2005) and fastest of the Ethernet standards. It defines a version of Ethernet with a **nominal data rate of 10 Gbit/s**, ten times faster than gigabit Ethernet. It is currently specified by a supplementary standard, **IEEE 802.3ae**, and will be incorporated into a future revision of the IEEE 802.3 standard.

IEEE Std 802.3ae-2002 defines the operation of the 802.3 Media Access Control(MAC) at 10Gbps for **full-duplex operation only**, while preserving the 802.3 frame format, including minimum/maximum frame size.



Several Physical Coding Sublayers known as **10GBASE-X**, **10GBASE-R**, and **10GBASE-W** are specified, as well as significant additional supporting material for a 10 Gigabit Media Independent Interface (XGMII), a 10 Gigabit Attachment Unit Interface (XAUI), a 10 Gigabit Sixteen-Bit Interface (XSBI) and management.

The **10 Gigabit Media Independent Interface** provides an interconnection between the Media Access Control (MAC) sublayer and Physical Layer entities (PHY). This **XGMII supports 10 Gb/s** operation **through** its **32-bit-wide** transmit and receive data paths. The Reconciliation Sublayer provides a mapping between the signals provided at the XGMII and the MAC/PLS service definition.

There are a number of different physical layer (PHY) standards. The letter "X" denotes 8B/10B signal encoding and is used for copper interfaces. The most common optical variety is referred to as LAN PHY, used for connecting directly between routers and switches. Although called LAN, this can be used with 10GBase-LR and -ER up to 80 km. LAN PHY uses a line rate of 10.3 Gbit/s and a 66B encoding. WAN PHY (denoted by a "W") encapsulates Ethernet frames for transmission over a SDH/SONET STS-192c channel.

10GBASE-LX4 — uses wavelength division multiplexing to support ranges of between 240 m and 300 m over deployed (FDDI-grade) multi-mode cabling. Also supports 10 km over single-mode fiber. Uses wavelengths around 1310 nm.

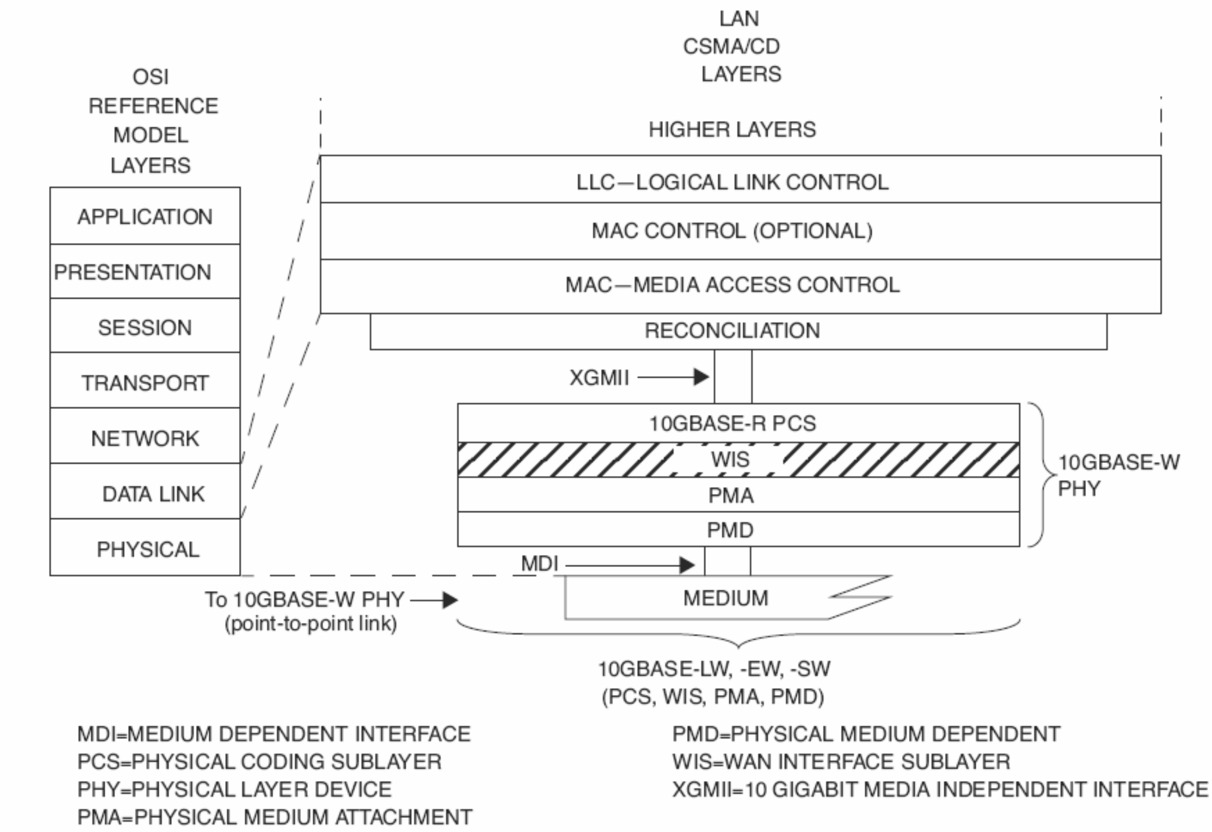
10GBASE-SR ("short range" - using 850 nm) — designed to support short distances over deployed multi-mode fiber cabling, it has a range of between **26 m and 82 m** depending on cable type (FDDI-grade). It also supports **300 m** operation over a new 2000 MHz·km 50µm multi-mode fiber.
10GBASE-LR ("long range" - using 1310 nm) — this standard supports distances of **up to 10 km** over single-mode fiber.
10GBASE-ER ("extended range" - using 1550 nm) — this standard supports distances **up to 40 km** over single-mode fiber. Recently several manufacturers have introduced 80-km-range ER pluggable interfaces.

10GBASE-SW, **10GBASE-LW** and **10GBASE-EW** — These varieties use the WAN PHY, designed to interoperate with OC-192/STM-64 SONET/SDH equipment using a light-weight SDH/SONET frame. They correspond at the physical layer to 10GBASE-SR, 10GBASE-LR and 10GBASE-ER respectively, and hence use the same types of fiber and support the same distances (aj rovnaké vlnové dĺžky – 850, 1310 a 1550nm). (There is no WAN PHY standard corresponding to 10GBASE-LX4.)

10GBASE-CX4 — Copper interface using InfiniBand CX4 cables and InfiniBand 4x connectors for short-reach (**15m maximum**) applications (such as aggregation switch to router). This is currently the lowest-cost per port interface at the expense of transmission range.

Unlike earlier Ethernet systems, 10 gigabit Ethernet (for any nontrivial distance) is so far based mostly on the use of optical fiber connections (with the exception of -CX4). However, the IEEE is developing a standard for 10 gigabit Ethernet over twisted pairs (**10GBASE-T**), using **Cat-6A** cable and **planned for** approval in **2006**. Additionally, this developing standard is moving away from half-duplex design, with broadcasting to all nodes, towards **only** supporting switched **full-duplex networks**. It is claimed that this system has high compatibility with earlier Ethernet and IEEE 802 networks.

WAN Interface Sublayer (WIS), type 10GBASE-W



Overview

The WAN Interface Sublayer (WIS) is an optional PHY sublayer that may be used to create a 10GBASE-W PHY that is data-rate and format compatible with the SONET STS-192c transmission format defined by ANSI, as well as the Synchronous Digital Hierarchy (SDH) VC-4-64c container specified by ITU. The purpose of the WIS is to allow 10GBASE-W equipment to generate Ethernet data streams that may be mapped directly to STS-192c or VC-4-64c streams at the PHY level, without requiring MAC or higher-layer processing. The WIS therefore specifies a subset of the logical frame formats in the SONET and SDH standards. In addition, the WIS constrains the effective data throughput at its service interface to the payload capacity of STS-192c / VC-4-64c, i.e., 9.58464 Gb/s. Multiplexed SONET/SDH formats are not supported.

The WIS does not render a 10GBASE-W PHY compliant with either SONET or SDH at any rate or format. A 10GBASE-W interface is not intended to interoperate directly with interfaces that comply with SONET or SDH standards, or other synchronous networks. Such interoperation would require full conformance to the optical, electrical, and logical requirements specified by SONET or SDH, and is outside the scope and intent of this standard. Operation over electrically multiplexed payloads of a transmission network is outside the scope of this standard.
From the perspective of the 10 Gb/s MAC layer, a 10GBASE-W PHY does not appear different (in either the functions or service interface) from a PHY without a WIS, with the exception of sustained data rate. However, a 10GBASE-W interface may interoperate only with another 10GBASE-W interface.

In terms of the open-systems-interconnection (OSI) networking model, 10 GE is a Layer 2 protocol. It does not use the same operating parameters or specification method as SONET but is compatible and within the same operating range. This allows 10 GE to operate over the WAN infrastructure. On the photonic hardware side, the physical media dependent (PMD) sublayer will involve OC-192 (10 Gb/s) components.

The PHY layer includes everything from the medium access controller on down. This layer is divided into the physical code sublayer (PCS), WAN interface sublayer (WIS), physical medium attachment (PMA), and physical medium dependent (PMD). When operating in WAN compatible mode, the PHY engages the WIS; when operating in LAN mode, the PHY bypasses the WIS. The PCS provides the encoding which is 64b/66b for both the LAN and WAN. The WIS layer inserts a SDH/SONET compatible overhead subset and performs SDH/SONET compatible scrambling and management functions.

The LAN PHY uses similar cabling and transceivers. The two major differences between the LAN PHY and the WAN PHY are the LAN standard's support for multimode fiber and its reduced overhead, which results in a 7% increase in speed. Vendors will eventually support both PHYs in future products by incorporating techniques to convert from one flavor to the other.

The IEEE task force rejected conformance to synchronous-optical-networking (SONET) jitter, stratum clock, and other optical specifications, as these techniques added complexity and costs that were unnecessary and possibly undesirable in the Ethernet environment. The inclusion of a SONET framing sublayer in the WAN PHY, however, allows 10-GE switches and routers to connect to SONET access equipment and use the SONET infrastructure for Layer 1 transport. These links remain asynchronous Ethernet links, presenting Layer 2 Ethernet packets to the SONET infrastructure with just enough SONET management information that the link may be managed as a SONET link.

However, the similarity between SONET and the 10-GE WAN PHY stops there; SONET systems use synchronized, high-accuracy stratum clocks to form a synchronous clock hierarchy. These high-accuracy clocks support regenerators that re-create the signals moving from one SONET segment to the next. On the other hand, WAN-compatible 10 GE remains an asynchronous protocol and operates like any other asynchronous network interface. Therefore, there is no need to support the expensive timing, clocking, and jitter requirements of the synchronous optical network for which every device shares the same precisely aligned stratum clock. So the benefits of transport, speed, and reliability have been retained, while the cost and complexity of SONET has been avoided. As a result, 10 GE is a logical path forward for future networks, providing the industry with a robust Ethernet solution that maintains the simplicity of the Ethernet yet leverages the considerable installed infrastructure while offering superior network reliability.

10 Gigabit Ethernet in Metropolitan and Storage Applications

Gigabit Ethernet is already being deployed as a backbone technology for dark fiber metropolitan networks. With appropriate 10 Gigabit Ethernet interfaces, optical transceivers and singlemode fiber, network and Internet service providers will be able to build links reaching 40 km or more (Figure 3), encircling metropolitan areas with city-wide networks. 10 Gigabit Ethernet now enables cost-effective, high-speed infrastructure for both network attached storage (NAS) and storage area networks (SAN). Prior to the introduction of 10 Gigabit Ethernet, some industry observers maintained that Ethernet lacked sufficient horsepower to get the job done. 10 Gigabit Ethernet can now offer equivalent or superior data carrying capacity at latencies similar to many other storage networking technologies, including Fiber Channel, Ultra160 or 320 SCSI, ATM OC-3, OC-12, and OC-192, and HIPPI (High- Performance Parallel Interface). Gigabit Ethernet storage servers, tape libraries, and compute servers are already available; 10 Gigabit Ethernet end-point devices will soon appear on the market as well.

10 Gigabit Ethernet in Wide Area Networks

10 Gigabit Ethernet enables ISPs and NSPs to create very highspeed links at a very low cost from co-located, carrier-class switches and routers to the optical equipment directly attached to the SONET/SDH cloud. 10 Gigabit Ethernet, with the WAN PHY, also allows the construction of WANs that connect geographically dispersed LANs between campuses or points of presence (POPs) over existing SONET/SDH/TDM networks. 10 Gigabit Ethernet links between a service provider’s switch and a DWDM device or LTE (line termination equipment) might in fact be very short – less than 300 meters.

Ethernet Over SONET

Because of the proliferation of LANs that require the ability to intercommunicate with other LANs across the country and around the world, Ethernet carriers have struggled with the best solution for handling all-Ethernet traffic. One new means of transporting Ethernet traffic is the use of metro area networks (MANs). These are being developed as stepping stones between LANs and WANs.After weighing cost, distance, bandwidth, and traffic management requirements, several Ethernet transmission options were suggested and implemented:•Ethernet over wavelengths (EOW)•Ethernet over SONET/SDH (EOS)•Optical Ethernet (native Ethernet over long-haul fiber)•Ethernet in the first mile (EFM) over copper or fiberIt soon became clear that EOS was emerging as the most popular choice as the MAN connection. Flexible and guaranteed bandwidth puts EOS ahead of the others.Note:Much of the discussion about Ethernet over SONET also applies to Ethernet over Synchronous Digital Hierarchy (SDH), the international version of SONET.

Note:Ethernet frames fit into the payload side of an STS-1 frame.

10GBASE-T

Objectives

The 10GBASE-T task force (formally known as IEEE 802.3an ™) group's initial goal was to develop 10 Gigabit Ethernet that would operate over horizontal, structured, twisted-pair cabling. Several of the key objectives that the group would need to work on would include:

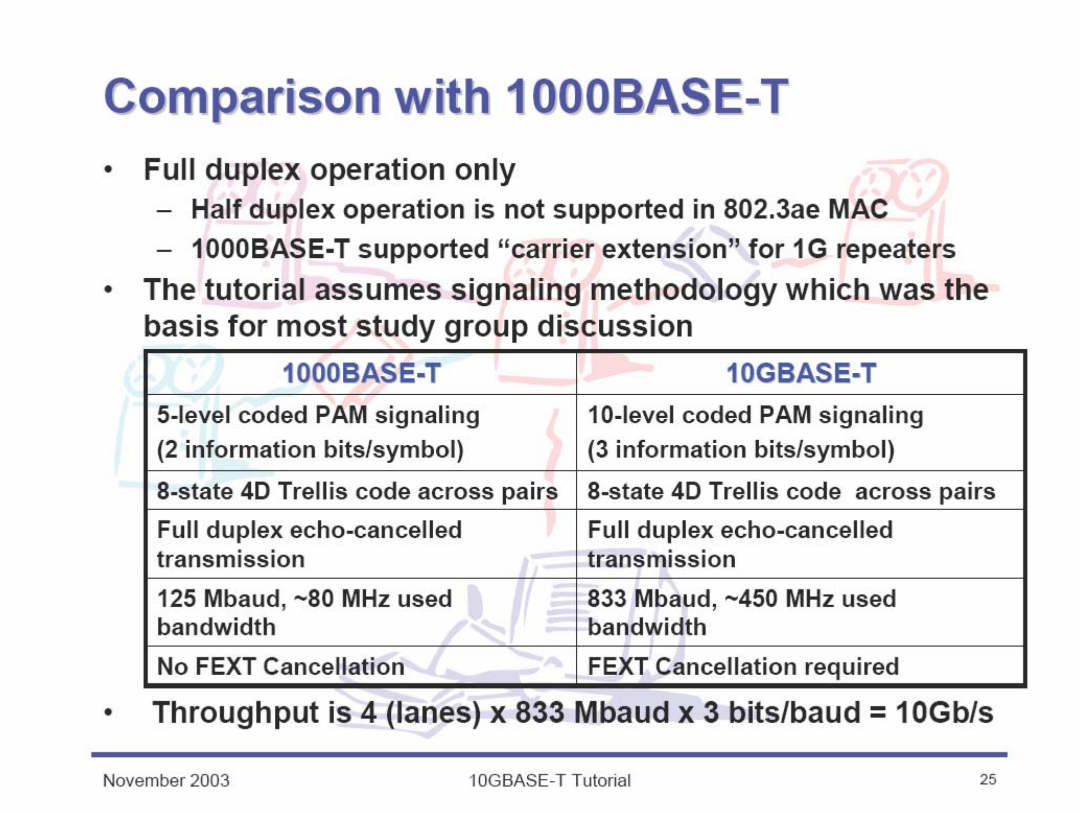
- Preserving the 802.3/Ethernet frame and size formats at the MAC interface
- Support a speed of 10 Gb/s at the MAC interface
- Support full duplex operation
- Support operation over a 4 connector structured 4-pair, twisted-pair copper cabling for all supported distances
- Satisfy CISPR/FCC "Class A" emissions requirements
- Support a BER of 10^{-12} on all supported distances and classes

10GBASE-T Cabling Objectives

The main cabling objectives for the 10GBASE-T task force are to:

- Support operation over 4-connector structured 4-pair twisted-pair copper cabling for all supported distances and classes
- Define a single 10 Gb/s PHY that would support links of:
    - At least 100m on four-pair Class F/Category 7 balanced copper cabling
    - At least 55m to 100m on four pair Class E/Category 6 balanced copper cabling
- Satisfy CISPR/FCC "Class A" emissions requirements

One of the key objectives of the 10GBASE-T standard is to support copper media that is representative of either class E or class F structured cabling.



Comparison with 1000BASE-T

- Full duplex operation only
    - Half duplex operation is not supported in 802.3ae MAC
    - 1000BASE-T supported "carrier extension" for 1G repeaters
- The tutorial assumes signaling methodology which was the basis for most study group discussion

1000BASE-T	10GBASE-T
5-level coded PAM signaling (2 information bits/symbol)	10-level coded PAM signaling (3 information bits/symbol)
8-state 4D Trellis code across pairs	8-state 4D Trellis code across pairs
Full duplex echo-cancelled transmission	Full duplex echo-cancelled transmission
125 Mbaud, ~80 MHz used bandwidth	833 Mbaud, ~450 MHz used bandwidth
No FEXT Cancellation	FEXT Cancellation required

- Throughput is 4 (lanes) x 833 Mbaud x 3 bits/baud = 10Gb/s

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The 10GBASE-T application will utilize a 12-level, pulse amplitude modulation (PAM-12) encoding scheme to transmit data at a rate of 825 million symbols per second (825 Mbaud). Transmission will employ full-duplex (transmitting and receiving information at the same time) operation over all 4-pairs for a data rate of 2.5 Gb/s per twisted-pair. Sophisticated crosstalk (both near-end and far-end) and return loss cancellation technology will be employed to increase available signal-to-noise margins.

The IEEE 802.3an standard is anticipated to publish in July 2006.

CISCO 10GBASE XENPAK MODULES

The range of Cisco® 10GBASE XENPAK modules offers customers a wide variety of 10 Gigabit Ethernet connectivity options for data center, enterprise wiring closet, and service provider transport applications.
Main features of Cisco 10GBASE XENPAK modules include:

- Supports 10GBASE Ethernet
- Hot-swappable input/output device plugs into an Ethernet XENPAK port of a Cisco switch or router to link the port with the network
- Provides flexibility of interface choice
- Supports "pay-as-you-populate" model
- Supports the Cisco quality identification (ID) feature that enables a Cisco switch or router to identify whether the module is a Cisco certified and tested XENPAK module
- Dimensions (DxWxH): 4.76"x1.42"x0.47" (121x36x18 mms)

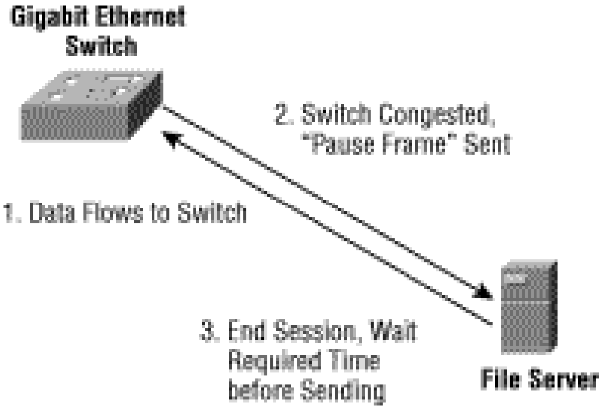
CISCO XENPAK-10GB-CX4
The Cisco 10GBASE-CX4 Module supports link lengths of up to 15 meters on CX4 cable.
CISCO XENPAK-10GB-LX4
The Cisco 10GBASE-LX4 Module supports link lengths of 300 meters on standard Fiber Distributed Data Interface (FDDI) grade multimode fiber (MMF). To ensure that the specifications reported in Table 1 are met, the transmitter output should be coupled through a mode conditioning patch cord.
CISCO XENPAK-10GB-SR
The Cisco 10GBASE-SR Module supports a link length of 26 meters on standard FDDI grade MMF. Up to 300-meter link lengths are possible when using 2000 MHz/km MMF (OM3).
CISCO XENAPK-10GB-LR
The Cisco 10GBASE-LR Module supports a link length of 10 kilometers on standard single-mode fiber (SMF) (G.652).
CISCO XENPAK-10GB-ER
The Cisco 10GBASE-ER Module supports a link length of up to 40 kilometers on SMF (G.652).
CISCO XENPAK-10GB-ZR
The Cisco **10GBASE-ZR** Module supports link lengths of up to about **80 kilometers on SMF**. This interface is **not part of** the 10 GbE **standard** but is built according to Cisco optical specifications reported in Table 3.

Full Duplex

While listening before talking applies to half-duplex systems, the 1997 IEEE 802.3x standard describes full-duplex Ethernet operation between a pair of stations. Simultaneous transmit and receive is over twisted-pair or fiber-optic cables that support two unidirectional paths. Besides the cabling, the Ethernet devices must support simultaneous transmit and receive functions.The 1997 standard calls for traffic flow control, called MAC Control Protocol and PAUSE. If traffic gets too heavy, the control protocol can pause the flow of traffic for a brief time

The IEEE 802.3x **committee** is examining a method of flow control for full-duplex Ethernet. This mechanism is set up between the two stations on the point-to-point link. If the receiving station at the end becomes congested, it can send back a frame called a "pause frame" to the source at the opposite end of the connection, instructing that station to stop sending packets for a specific period of time. The sending station waits the requested time before sending more data. The receiving station can also send a frame back to the source with a time-to-wait of zero, instructing the source to begin sending data again. (See Figure 9.)

Figure 9: Operation of IEEE 802.3x Flow Control



This flow-control mechanism was developed to match the sending and receiving device throughput. For example, a server can transmit to a client at a rate of 3000 pps. The client, however, may not be able to accept packets at that rate because of CPU interrupts, excessive network broadcasts, or multitasking within the system. In this example, the client sends out a pause frame and requests that the server delay transmission for a certain period of time. This mechanism, though separate from the IEEE 802.3z work, complements Gigabit Ethernet by allowing gigabit devices to participate in this flow-control mechanism.

Kategórie TP káblov

Category 5 cable

- commonly known as Cat 5, is an unshielded twisted pair type cable
- Its specific standard designation is EIA/TIA-568
- Cat 5 cable typically has three twists per inch of each twisted pair of 24 gauge copper wires within the cable.
- Another important characteristic is that the wires are insulated with a plastic (FEP) that has low dispersion, that is, the dielectric constant of the plastic does not depend greatly on frequency. Special attention also has to be paid to minimizing impedance mismatches at connection points.

The other well known flavour of this type of cable is the 10 Mbit/s (16Mhz) Category 3 cable. Less well known is the 20 Mbit/s Cat 4. Cat 4 offered only a small advance in speed over Cat3, and was generally ignored in favour of Cat 5. Cat 1 and Cat 2 are 1 Mbit/s systems for voice and low-speed data.

Patch leads created from Cat 5 are often terminated with RJ-45 electrical connectors. Normal Cat 5 cables are wired "straight through" and connect a computer to a hub. In other words, pin 1 is connected to pin 1, pin 2 to pin 2, etc. The RJ-45 pinout for a Cat 5 cable can either be TIA-568A or TIA-568B. TIA-568A is used by some phone systems and Token Ring. Most everything else, such as the **Ethernet** standards 10BASE-T and 100BASE-TX, **use TIA-568B**.

In Ethernet, "crossover" Cat-5 cables are used to connect two hubs together, in which pairs two and three are reversed. Crossover cables can also be used to connect two PC's NICs directly (with no intervening hub). See the TIA-568B article for a pinout diagram.

Cat 5e cable is an enhanced version of Cat 5 for use with 1000 Base-T networks, or for long-distance 100 Base-T links (350 m, compared with 100 m for Cat5). It must meet the EIA/TIA 568A-5 specification.

Cat 6 cable (Class E) is defined by the ANSI TIA/EIA 568B-2.1. It is suitable for 1000 Base-T (gigabit) Ethernet up to 100 m. Specification defines balanced cabling characteristics over a maximum bandwidth of 250 MHz.

The Class F cabling specification (also referred to as **category 7** cabling) defines balanced cabling characteristics over a maximum bandwidth of 600 MHz.

Augmented category 6/class E cabling requirements will extended the frequency characterization of existing category 6/class E cabling requirements to 500 MHz, specify increased insertion loss headroom (equivalent to class F performance), and include new requirements for the parameter of alien crosstalk.

The designation U/UTP defines a balanced cable type in which four twisted-pair conductors are surrounded by a cable sheath. The designation F/UTP defines a balanced cable type in which an overall metal foil encloses all four twisted conductor pairs and then the metal foil is surrounded by a cable sheath. The designation S/FTP defines a balanced cable type in which each of the four twisted conductor pairs are enclosed by a foil screen and then all pairs are surrounded by a braid screen and an overall cable sheath.